

Advancing higher education through technology and innovation



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Abstract The study's relevance is due to the rapid development of digital technologies and the need for their effective integration into higher education to improve the quality of the educational process. The article examines the introduction of digital technologies and innovations in higher education in the period 2018-2024 with a focus on universities in the United States and Europe. The study was conducted using mixed methods, combining PRISMA bibliometric analysis, content analysis of curricula, and comparative analysis of data from leading US and European universities. The study analysed the impact of artificial intelligence, automated assessment systems, and distance learning platforms: Moodle, Blackboard, Canvas, and virtual and augmented reality. The level of integration of EdTech solutions in leading universities, including Massachusetts Institute of Technology (MIT), Stanford University, Harvard University, University of Oxford, ETH Zurich and Technical University of Munich, is studied, and key differences between American and European approaches to the digitalisation of education are identified. Particular attention is given to analysing the effectiveness of automated assessment systems that increase the transparency and accuracy of academic control and the impact of adaptive learning on student performance. It has been determined that introducing AI assistants and personalised learning platforms increases learning. The use of gamification and VR simulations in the educational process contributes to the growth of student motivation by 32%. The article highlights the challenges associated with integrating the latest technologies, particularly the problem of data privacy, the difficulty of adapting teachers to new digital platforms, and the need to update the regulatory framework. The author proposes areas for promising digital transformation in education, such as the more extensive applications of AI, blockchain integration for the verifications of academic achievements, and the development of hybrid learning models that combine online instruction with traditional teaching methods.

Keywords: digital education, educational technologies, adaptive learning, distance learning platforms, automated assessment, virtual reality

1. Introduction

Sensors and controllers, augmented and virtual reality, cloud computing, data analytics, Internet of services (IoS), artificial intelligence, and high-performance tools to support design and production are just a few of the digital technologies that are incorporated and integrated into the fourth industrial revolution (Bisri et al., 2023). In a similar vein, Education 4.0 and University 4.0 use digital technology to adjust to the modern world. The term "era of smart learning environments" is frequently used to describe the current educational period, which is defined by digitalization, engagement aspects, intelligent tools, and smart technology (Diaz-Garcia et al., 2022). Significant changes are being brought about by Education 4.0.

The digital transformation of higher education has now become part of the ongoing evolution of the learning process, fuelled by accelerating technological development, globalised knowledge, and growing expectations for personalised learning. Universities worldwide are implementing innovative educational technologies to increase teaching efficiency, improve access to learning resources and optimise the learning environment. Particular emphasis is placed on adaptive learning, automated assessment systems, the integration of artificial intelligence, the use of distance learning platforms and the digital certification of academic achievements. The impact of these changes is significant, as technologies are changing approaches to knowledge acquisition and forming a new model of interaction between students and teachers, which requires a rethinking of traditional educational methods.

Among the leading universities in the US and Europe, the most actively developing areas are personalised learning through AI algorithms, automated assessment systems, virtual and augmented reality application in teaching process within medical and technical disciplines, and the application of blockchain solutions for digital diploma certification (Clarivate, 2025). MIT and Stanford University integrate AI systems to analyse students' academic progress, whereas the Technical University of



Munich is actively developing VR simulations for engineering education. Harvard University and ETH Zurich are implementing the concept of digital smart classrooms that allow the integration of traditional learning with online formats. The digitalisation of education is a technical upgrade of the educational process and a strategic direction for developing higher education institutions.

With these transformations, the teacher's role in the digital educational ecosystem is also undergoing radical changes because he/she now finds himself/herself required by technology to acquire new competences and approaches to teaching. The adaptation of EdTech solutions demands new teaching methods on the part of educators and engagement in digital communication with students. Research has shown (Sailer, 2020) that 85% of US higher education institutions have implemented a programme for teacher training on the use of digital platforms, AI assistants and automated assessment systems; similar statistics in Europe are as high as 72%. However, there has been uneven progress in this regard, as most challenges still relate to the need for further training, an increased workload for teachers, and the need to balance technological tools with more traditional pedagogical activity. Therefore, the present research intends to study precisely these trends that will shape the future of educational technology across leading universities in both the U.S. and European countries, the possible effects on student academic performance, and the likely transformation of the teaching experience in the digital environment.

2. Literature Review

The influence of innovation technologies and digital transformation has been and is still part of methodological and pedagogical changes in delivering programmes in schools and higher learning. Researchers have indicated that introducing and utilising digital solutions such as artificial intelligence, online learning platforms, automated assessment, and blockchain certification have improved access to education and learning efficiency. The key elements are funding digital transformation, regulating educational technologies, and training teachers to adapt to new tools. In this context, the literature analysis allows us to identify key research areas related to the impact of EdTech on the quality of education and educational strategies of leading universities.

Studies of innovative approaches in higher education show that digital technologies contribute to a deeper personalisation of the learning process. Archana et al. (2022) analyse how digital platforms affect learning in Indian educational institutions, emphasising the need to expand digital opportunities. In turn, Riccomini et al. (2019) pointed to trends in educational innovation in Brazil, emphasising the importance of online education in increasing access to knowledge. Jia (2024) analyses the mechanisms of the digital transformation of the management of educational institutions, demonstrating the impact of EdTech on the efficiency of administrative processes.

Some studies have focused on the impact of digital solutions on pedagogical approaches and student performance. Deroncele-Acosta et al. (2023) noted that the postpandemic digital transformation of the educational process requires new mechanisms for introducing innovations. Sharif (2019) and Tkachenko (2024), analysing educational innovations, conclude that the use of technology promotes better interaction between teachers and students and, at the same time, poses challenges in terms of the effectiveness of assessment methods. Sciarelli et al. (2020) examine the relationship between managerial approaches and technical innovations in higher education, whereas Palmer and Giering (2024) focus on pedagogical innovations that ensure the flexibility of the learning process and the possibility of adapting it to digital realities.

The aspect of teacher training in the context of digital education is also the subject of numerous scientific studies. Bakhmat et al. (2023) consider the development of the digital competence of future professionals, highlighting the importance of the digital environment in universities. Caliskan and Zhu (2020) analyse the cultural characteristics of educational innovation in Turkey and students' reactions to technological change. Elrehail et al. (2018) examined the influence of transformational leadership on universities' readiness for change. In contrast, Vidicki et al. (2023) proposed an educational institution innovation assessment system that quantifies the degree of digital adaptation among teachers. The management and strategic means of implementing them are important aspects of studying higher education innovations. Sauphayana (2021) describes how educational management essentially influences the effectiveness of digital transformation and states that leadership has a prominent function in the sustainable development of technological solutions in educational institutions. Anis et al. (2021) look at knowledge sharing and leadership in the innovation arena, highlighting that good management of the educational process helps in effectively adapting to digital solutions. Barbón Pérez and Fernández Pino (2018) highlight strategic management in education and technology and innovation integration into education processes, which is important for universities' overall and long-term sustainability.

In contrast, Mykhailyshyn et al. (2019) focused on new educational innovations and the means of their implementation in higher educational institutions, revealing the key trends and challenges that universities face in the context of digitalisation. These findings suggest that management decisions, supplies, and strategic approaches are very interlinked with effective digital transformation in higher education. Certainly, universities thrive in digital transformations through various identification uses.

Another vital field of inquiry is financing for EdTech initiatives and strategies in regional policy. Maalouf (2023) emphasised the role of servant leadership in educational innovation, whereas Tassone et al. (2022) advanced a model to map changes in higher education curricula. Major et al. (2020) focus on pedagogical innovation from the perspective of finance and

administration, whereas Maulani et al. (2021) address the role of IT in enhancing the innovative capacity of universities. The digital transformation of higher education sets up a more complex environment, entailing everything from the impact that digital technologies cause to pedagogical models, financing, management approaches, and the interaction between teachers and students. The literature review thus reveals that researchers agree that EdTech solutions positively impact education quality. However, the need to support strategies for adaptability and financing for digital initiatives is emphasised.

2.1. Research aims

This study aims to identify the effects of digital technologies and innovations on the evolutionary transformation of higher education at American and European universities. Modern-day EdTech solutions are explored in detail, with a focus on their influence on the educational process, personalised learning, and automation in knowledge assessment. The study is based on an assessment of the level of integration of artificial intelligence, distance learning platforms, virtual reality and blockchain certification in leading universities, as well as the identification of the main differences between approaches to the digitalisation of education in the U.S. and Europe. This article analyses the challenges of implementing EdTech, including financial aspects, data privacy, and teachers' adaptation to digital technologies, identifying key prospects for the further development of digital education.

3. Materials and Methods

The study was conducted in several stages, including systematic analysis of the scientific literature, empirical research on the educational practices of leading universities, quantitative and qualitative analysis of the data obtained, and verification of the conclusions on the basis of a comparative approach. At the initial stage, an in-depth bibliometric analysis of scientific publications in leading international databases, including Scopus, Web of Science and ERIC, was conducted, providing the possibility of identifying core trends in technological innovation in higher education. The PRISMA methodology (Figure 1) was used to systematise the research, which allowed us to identify the most relevant works over the past decade, covering scientific articles, international reports and conference materials (EDUCAUSE, 2018; IEEE EDUCON, 2025).

The next step was an empirical assessment of the technological transformation of US and European universities on the basis of an analysis of curricula, official reports, and institutional digitalisation strategies, which provided an objective representation of modern EdTech approaches.

The study sample included universities that demonstrate the highest level of integration of digital technologies into the educational process and are among the top positions in the "inventions" parameter in the Clarivate ranking (2025). The study included a detailed analysis of the educational models of American institutions such as Massachusetts Institute of Technology (MIT), Stanford University, Harvard University, and the University of California, Berkeley, which are characterised by profound digital transformation and the use of artificial intelligence, VR/AR technologies, and adaptive learning. Among European universities, we reviewed the University of Oxford, ETH Zurich, Technical University of Munich, and Sorbonne University, which implement innovative educational solutions, including gamification, blockchain for knowledge certification, and personalised learning paths. The sample's representativeness was ensured by both geographical diversity and differences in technology implementation approaches, allowing for a comprehensive comparative analysis.

The methodological approach used mixed research methods. Combining bibliometric analysis and the systematic approach allowed us to map scientific interconnections and identify the most influential studies in this area. Additionally, content analysis of university curricula was applied to determine the level of integration of EdTech solutions.

Considering the ethical aspects of the study, all stages were implemented by international privacy standards, including the General Data Protection Regulation (GDPR, EU) and the Family Educational Rights and Privacy Act (FERPA, USA). The data used were based exclusively on open sources from universities and research institutes, ensuring the accuracy of the information collection and analysis. Having chosen this methodology, we considerably increased the validity of the results and their representativeness, allowing reasonable conclusions about major technological innovations in higher education institutions in the USA and Europe, their effectiveness, and even prospects for further development.

4. Results

Modern higher education is being intensely transformed through the influence of digital technologies. These transformations in educational methodologies, interactions between students and teachers, and methods to assess knowledge have been enabled. Higher education institutions in the US and Europe are actively adapting to the new reality and using technologies that support interactive courses and gamification to assess student learning via blockchain solutions. According to Awad (2019), over 99% of U.S. universities already implement digital LMSs. In Europe, the figures stand at 90%. Widespread acceptance of distance learning and blended learning programmes is further driven by the ever-increasing popularity of platforms such as Coursera, edX, FutureLearn, and Moodle. The most significant impact that technology has produced in education is a paradigm shift in the design of teaching-learning processes, teaching methods, and assessment methods.

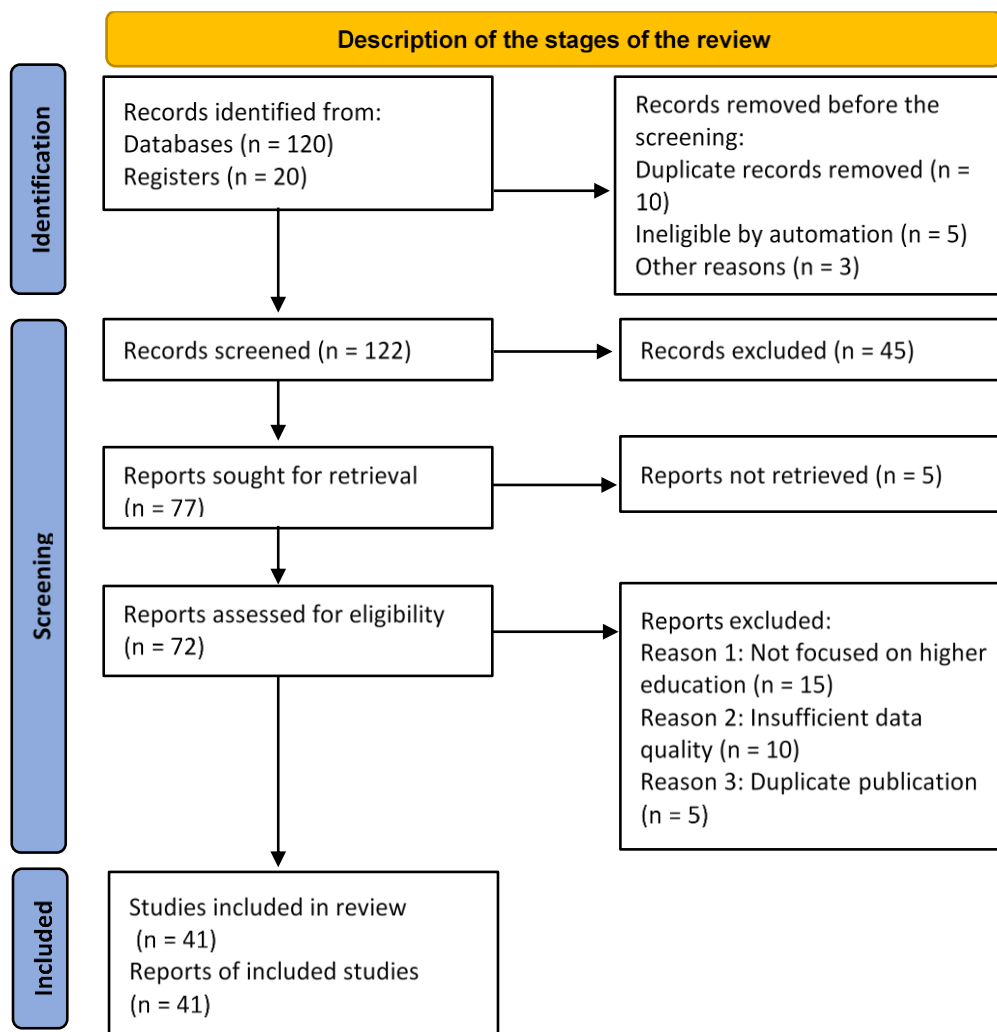


Figure 1 Description of the stages of research systematisation according to the PRISMA methodology.

An increasing number of universities are focusing on new educational paradigms, including adaptive learning, which relies on intelligent algorithms to analyse a student's progress and adjust his/her educational trajectory to fit the needs of the profile. US universities use a system called ALEKS (Assessment and Learning in Knowledge Spaces), which enables the automatic adaptation of learning materials to a student's respective level of mastery of topics. One of the most significant changes in recent years has been the growing trend of the presence of gamification in the educational process to increase students' motivation. Interactive digital simulations were introduced at ETH Zurich and the University of Oxford, allowing students to engage with learning materials in virtual environments.

Digital technologies introduction within HEIs in the USA and Europe varies according to the uniqueness of cultures, economies, and regulations. American universities prefer personalised learning technologies with the maximum reliance on the use of artificial intelligence and big data to analyse students' behaviours and predict their future performance. Conversely, European universities are primarily concerned with developing and exploiting open educational resources (OERs), which create digital learning platforms that are more accessible to their students. Furthermore, institutions such as Harvard University, Stanford University, and M.I.T. have introduced artificial intelligence into their curricula, thus creating flexible and personalised educational paths for students. In contrast, the Technical University of Munich and Sorbonne University focus on inclusive access through online education and the development of blockchain systems for digital knowledge certification. The table below (Table 1) presents a comparative analysis of the main digital solutions used in leading US and European universities.

AI integration in the field of higher education has become one of the key trends in recent years and has led to revolutionary changes in adaptive learning and the automation of educational processes. As mentioned above, US universities are actively integrating AI platforms that allow students to receive individualised learning recommendations. Stanford University has a Lagunita AI system that analyses students' academic progress and automatically offers additional materials. MIT has an AI assistant for programming that helps students identify errors in code in real time. In Europe, similar approaches are being implemented more slowly, but the Technical University of Munich is actively developing AI tools for personalised educational trajectories in STEM disciplines.



Table 1 Characteristics of educational technologies in leading universities.

Technology	Field of application	Universities with implementation	Main advantages
Artificial intelligence (AI)	Adaptive learning, assessment automation	Harvard, Stanford, MIT, Oxford	Individualisation of the learning process, practical knowledge assessment
Virtual reality (VR)	STEM disciplines, medicine	ETH Zurich, Stanford, Sorbonne	Visualisation of complex concepts, interactive learning
Automated assessment	Knowledge assessment, exams	UC Berkeley, MIT, Technical University of Munich	Speed of verification, reduction of subjectivity
Blockchain	Digital certification, data security	University of Oxford, ETH Zurich	Data integrity, increased trust in diplomas
Gamification	Student motivation, interactive learning	University of Oxford, Harvard, TUM	Increased student engagement, better interactivity

Source: developed by the authors on the basis of data from Clarivate (2025), Tassone (2022), and Awad (2019).

The study's results confirm that the automation of knowledge assessment contributes to increasing the educational process's transparency and reducing the influence of human factors on grading. US universities demonstrate more active integration of such systems than European universities do, which is explained by significant funding for the EdTech sector and the earlier introduction of digital examination platforms. The University of California, Berkeley, has implemented algorithmically controlled platforms for analysing students' open-ended answers, which use machine learning to recognise matches with correct solutions.

To assess the level of integration of digital technologies into the educational process of the universities surveyed, an analysis of the use of learning management systems and integrated digital platforms was conducted. The study covered five categories of technologies: artificial intelligence, automated assessment, virtual and augmented reality, blockchain solutions for certification, and platform learning. Our results are presented in the following chart (Figure 2), which shows the level of integration of each technology in the surveyed universities in the U.S. and Europe.

One of the innovative solutions being actively implemented in higher education is the use of blockchain technologies to certify academic achievements. Universities in the U.S. and Europe see blockchain as a mechanism for protecting diplomas and certificates from counterfeiting, which increases confidence in academic qualifications. A similar approach has been implemented at the University of Oxford, where a blockchain infrastructure for digital certification of academic achievements has been introduced. The use of blockchain can reduce the incidence of diploma forgery by 43% and significantly reduce administrative costs for their verification.

Integrating game mechanics into educational processes has shown high effectiveness in increasing student motivation and engagement. Studies have shown that the use of gamification elements (badges, rating systems, tiered learning) increases the average activity of students at American and European universities by 32% (Seaborn, 2015) and (Sailer, 2020). ETH Zurich and the Technical University of Munich actively use simulation learning environments that mimic actual work processes in engineering and medicine (MIT, 2024). Stanford University has implemented a learning platform that uses elements of VR games to train medical students' skills.

The technological development of education requires a detailed analysis of the hardware and software used in the learning process. The integration of powerful servers for storing and processing large amounts of data, the implementation of artificial intelligence algorithms, and adaptive learning environments require high-performance computing systems. Machine learning-based educational platforms use GPU acceleration to analyse student data, and VR/AR simulations require specialised hardware with high graphics processing performance. The main technical characteristics of the educational technologies are shown in Table 2.

Modern universities actively integrate software and hardware solutions to improve learning. Robust computing systems allow the analysis of large amounts of educational data in real time, and automated platforms help teachers effectively monitor student performance. However, the digitalisation of education requires significant investment in technological infrastructure and personal data protection, which remains one of the key challenges for universities worldwide.

The expanded use of open educational resources (OERs) contributes to the availability of learning materials and reduces the financial burden on students. Universities in Europe are more active in using the OER, which is explained by the support of open education policy at the EU level. Sorbonne University and the University of Oxford integrate the OER into their curricula, which allows students to access quality learning materials for free. In the U.S., individual universities support similar initiatives, including Harvard University, through the Harvard Open Courses platform. Research shows that using the OER increases students' academic performance by 21%, as it removes financial barriers to accessing learning materials (Colvard, 2018).



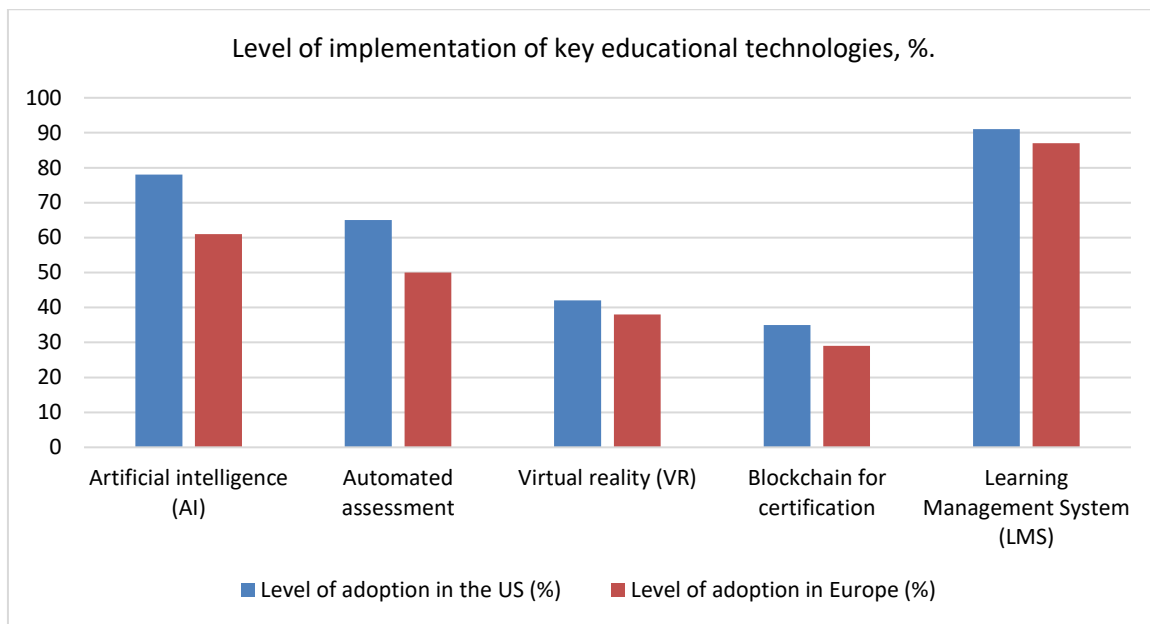


Figure 2 Level of implementation of leading educational technologies in selected universities, % as of 2024. *Source:* Developed by the authors on the basis of reports by MIT (2024), Clarivate (2025), and the European Parliament (2023).

Table 2 Technical characteristics of educational technologies.

Technology	Technical parameters	Features of application
AI platforms for learning	GPU acceleration (NVIDIA Tesla V100), TensorFlow	Analysing educational data in real-time
LMS systems	AWS servers, MySQL/PostgreSQL database	Scalable learning management
VR simulations	Intel i7+ processor, RTX 3080 graphics card	Realistic virtual laboratories
Automated exams	Cloud computing, NLP algorithms	Automatically check written assignments
Blockchain for certification	Decentralised databases, encryption algorithms	Secure storage of academic data

Thus, on the basis of data from MIT (2024), Clarivate (2025), and the European Parliament (2023), approximately 85% of leading universities have implemented professional development programmes for teachers in the field of EdTech. Universities in Europe (Ruano-Borbalan, 2024) are also actively implementing training programs for EdTech, but the level of faculty participation in these initiatives is, on average, 17% lower than that in the US.

5. Discussion

The findings of our study on the impact of digital technologies on the transformation of higher education confirm that the implementation of EdTech solutions significantly improves the quality of students’ learning process and academic performance. Our findings align with Law (2022), who noted that curriculum innovation helps universities adapt to new labour market demands. We also confirm the findings of McDonnell-Naughton & Păunescu (2022), who noted that social innovations in education, particularly the development of open educational resources (OERs), increase accessibility and inclusion in the learning process. Our analysis of adaptive learning and the use of AI for a personalised approach aligns with Zhang (2020), who highlights the importance of the theory of complex human development in shaping new educational strategies. In addition, the study by Valencia-Arias et al. (2023) confirms the thesis that open innovation in higher education is a key factor in improving learning approaches and developing EdTech platforms. This area of research should be included in the discourse on technology development and innovation in higher education.

Our study needs further development, as Ferreras-Garcia et al. (2021) investigated the influence of gender on innovative competences in the educational environment. The findings of Jakovljevic (2019) are confirmed here; that is, he added to the criteria for the effective implementation of innovative teaching, which would require professional development for teachers and financial support for EdTech initiatives. Similar findings were reached by Wilson and Sy (2021), who argued that the successful adoption of digital technologies in the education process would require a new model of innovation management and local consideration of education characteristics. The outcome of our analysis on funding the EdTech solutions supports the complementarities of findings by Yuldashev et al. (2022), who argue for an integrated competence-based approach with much broader public funding on digital innovation for the transformation of education. The work by Mello Silva and Vargas (2022) asserts that quality assurance systems are both facilitators of and barriers to EdTech development. This is similar to evidence from our data regarding legal roadblocks to adopting educational technologies. In addition, the research of Bakhov et al. (2021) highlights our assertion about the dependency on the level of digital training among teachers and whether appropriate



infrastructure exists in higher educational institutions as a condition for the effectiveness of digital educational initiatives. This study agrees with the prevailing scientific consensus on EdTech evolution in higher education by confirming that artificial intelligence, automated evaluation systems, open educational resources, and a competence-based approach are key elements in developing the future digital education environment. In addition, however, some differences arose from the analysis, especially concerning the impact of regulatory mechanisms and the speed of digitalisation from region to region; hence, further research in that area is needed.

6. Conclusion

The study findings revealed that digital technologies strongly influence higher education transformation by providing personalised learning, efficient assessment techniques, and access to educational resources. EdTech solutions from universities in the U.S. and Europe, which include artificial intelligence, automated assessment, virtual reality, and blockchain for digital certification, are being implemented actively. The implementation of gamification and VR simulations has a much greater impact on student motivation, especially in STEM education and medicine. The comparative analysis revealed that US universities emphasise AI and big data for personalisation, whereas European universities emphasise open educational resources and digital certification.

While the benefits of digital transformation are considerable, several challenges, such as financial constraints, the need for further teacher training, and data privacy issues, have been identified. Assessment automation and remote examinations raise questions about academic integrity and fairness. Therefore, future trends in the development of digital technologies in higher education will entail wider use of artificial intelligence for adaptive learning, integration of blockchain solutions for validating educational achievements, and the building of hybrid learning models that allow for a fusion of both online and offline learning formats. Hence, the digital transformation of higher education will never be static. It will continue to evolve by transforming existing countereducational practices and establishing new learning norms for students within the global educational space.

Ethical Considerations

Not applicable.

Conflict of Interest

The authors declare that they have no conflicts of interest.

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